UK CLIMATE PROJECTIONS

Supplement to: Interpretation for use of surface wind speed projections from the 11-member Met Office Regional Climate Model ensemble

S. Brown, P. Boorman, R. McDonald and J. Murphy, December 2009

As noted in the UK Climate Projections (UKCP09) Technical note on Wind (Brown *et al*., 2009, *http://ukclimateprojections.defra.gov.uk/images/stories/Tech_notes/UKCP09_wind_technote.pdf*), the RCM surface wind speeds show biases when compared to long-term climatological means derived from observations, or from atmospheric reanalysis datasets. Biases that vary with location and season that can be attributed to aspects of the parameterisation of unresolved orography and surface roughness. As such, Brown *et al.* recommend that when exploiting the RCM wind data, the consequences of these climatological biases should be carefully assessed in the context of the intended application.

There are a number of different methods and approaches to bias correction all of which have strengths and weakness. When deciding on which to use, the users should be aware of the assumptions and limitations of the particular method so that interpretations are made with these in mind. In practice, the optimal bias correction strategy is likely to be application-dependent, and it is recommended that users assess carefully the consequences of different approaches.

The UKCP09 Technical note on Wind (see Section 5) identifies some of the methods:

- For future projections of absolute surface wind speed:

  a. Deriving seasonally based change factors from the 11-member RCM ensemble for the specific metrics of interest (e.g. mean wind speed, 90th percentile daily wind speed) which then would be applied to observed values of the desired metric to provide eleven possible future projections.

- For time series of surface wind speed:

  a. A simple approach, for example, would be to express the simulated future daily values as fractional anomalies relative to the simulated long term historical average, and then apply those to the observed long term historical average to provide time series of absolute future values. Advantages – relatively simple and preserves the changes in the variability of wind speed projected by the RCMs. Limitation – does not account for variations in the historical simulation bias as a function of wind speed (see Figure 9 within the UKCP09 Technical note on wind).

  b. Derive a set of change factors from the RCM projections for corresponding percentiles of the wind speed distribution. These factors could then be applied to observed historical time series of wind speed to provide possible future time series. Advantage – accounts for historical simulation biases more comprehensively. Limitations – generated future time series would not account for potential changes in the characteristics of climate variability simulated by the RCMs, and the autocorrelation characteristics between consecutive wind events may be distorted by the application of time-varying change factors.

c. Correcting RCM-projected future time series to remove biases in the long-term average value estimated by comparing simulated and observed historical wind climatologies.

    - Advantage – may be applied quickly to all ensemble members for a large number of sites.

    - Limitation – lack of physical basiss for the downscaling as the distributions are forced to match the observations.

d. Adjusting observed historical time series according to correction factors which vary with wind speed, deduced by comparing simulated and observed distributions of daily values.

Users should be aware that any bias correction strategy will involve the assumption that the sign and magnitude of the climate change signal is not affected by the biases in the present day RCM climatology

An example method for the quantile correction of daily wind speed projections from the 11-member Met Office Regional Climate Model ensemble

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Validation of RCM wind speed data derived from the 11-member perturbed physics ensemble (PPE) indicates positive biases in the range of 10–30% across much of the Midlands and the south east of England (Brown *et al*. 2009). In SWERVE (component work package within *CREW http://www.extreme-weather-impacts.net/*), these biases and the need for correction factors were investigated for south east London by comparing each RCM ensemble member for the period 1961–1990 with a dataset of 5 km resolution monthly mean wind speed for the period 1969–1990 (available via the UK Meteorological Office* and UKCP09). This latter dataset is on a regular 5 km grid and so is not directly comparable with the RCM output. However, by comparing the grid cells corresponding to the South East London Resilience Zone (SELRZ) this data provides a relevant first-order comparison and, as shown in Figure 1 demonstrates a systematic overestimate of mean daily wind speed across the ensemble consistent with that provided by Brown *et al*. (2009), confirming their identified need for a bias correction strategy. A major difficulty is the absence of reliable long series of observed wind speed for the SELRZ but for comparison the mean wind speeds for a number of historical regional records are shown.

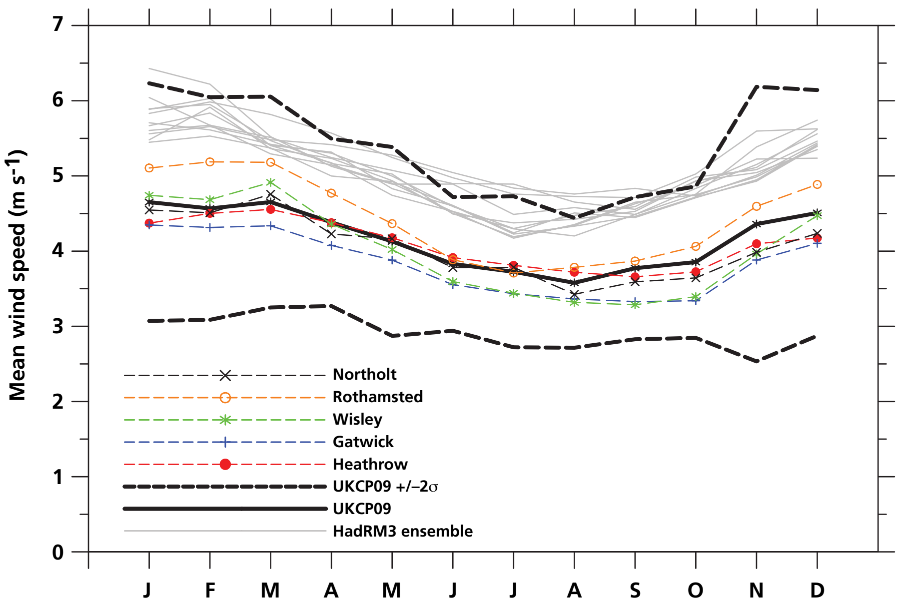
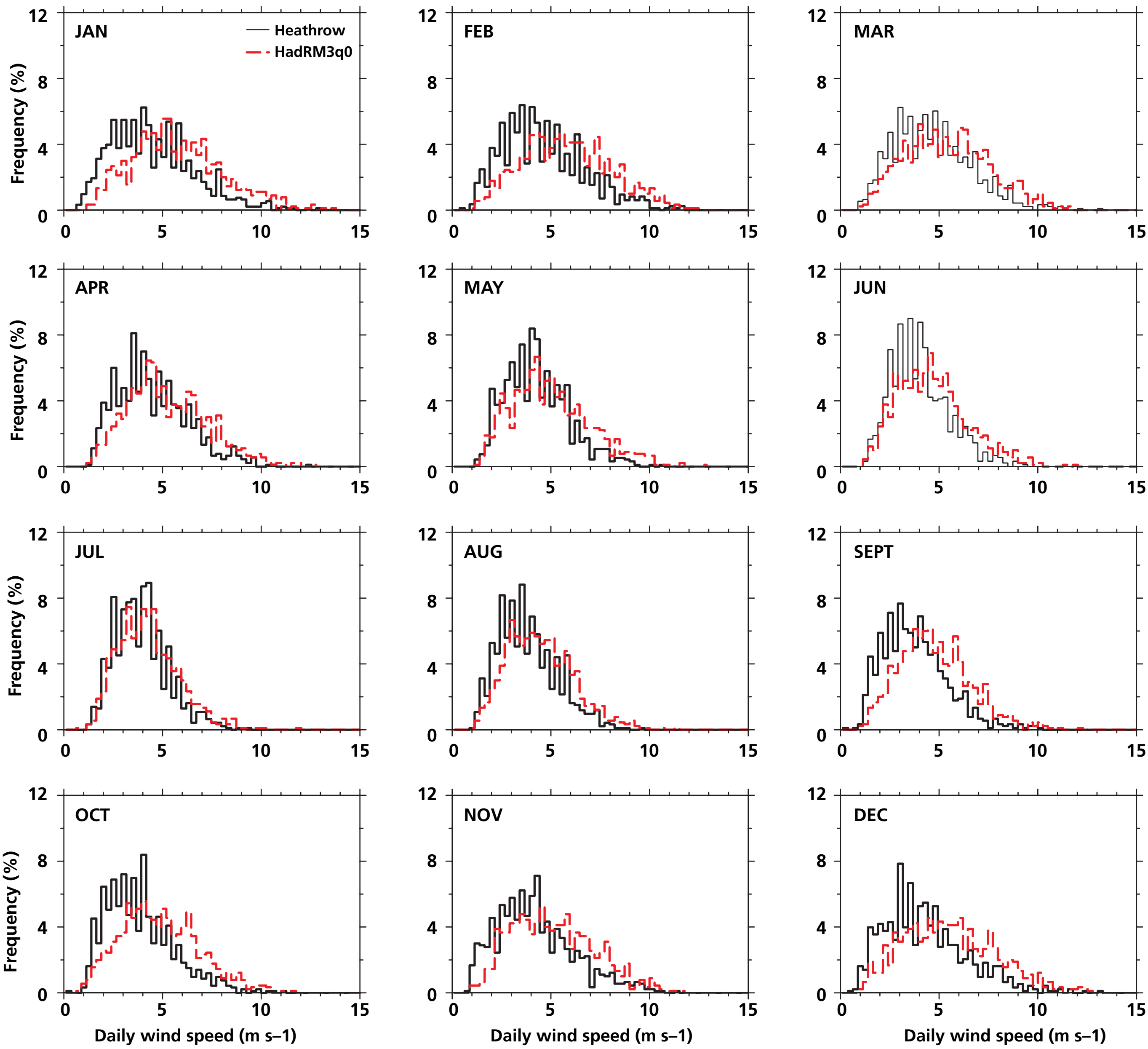


Figure 1: Mean monthly wind speed. HadRM3 ensemble (grey lines) refers to the 11 ensemble members for 1961–1990 for the grid cell corresponding to the SELRZ. UKCP09 (bold lines) refers to the means for the corresponding gridded monthly series based on observations, with the range of 2 standard deviations of the annual means also shown. The locations (dashed lines) refer to observed daily series in the region.

* http://www.metoffice.gov.uk/climatechange/science/monitoring/ukcp09/download/index.html

A simple correction based on monthly mean wind speeds could not be considered suitable because of possible differences in the distributions of the simulated daily RCM simulations compared with observations. This would be problematical for the examination of the high wind speeds that are of particular interest in SWERVE. The UKCP09 gridded observed dataset is at a monthly resolution and so is not appropriate for bias correction/downscaling of daily mean wind speed values. The nearest appropriate observed dataset is Heathrow which offers a complete, homogeneous record over the 1961–1990 period and closely reflects the monthly mean distribution of wind speed derived from the UKCP09 gridded dataset (see Figure 1). A comparison of the monthly distributions for Heathrow for 1961–1990 and one ensemble member over the same period is shown in Figure 2 which demonstrates that the differences between the two distributions are greatest in winter months.

Figure 2: A comparison of observed monthly distributions of mean daily wind speed (Heathrow) with ensemble member HadRM3q0 (before quantile correction) for the period 1961–1990



A quantile correction method was adopted to account for this bias by calculating the 10, 20, 30…90, 95 and 99th percentiles for the Heathrow daily wind speed time series on a monthly basis along with the corresponding percentiles for each of the RCM ensemble members. These quantiles were used as boundaries for a series of bins into which daily mean wind speed values may be assigned. Additional quantiles could easily be used to provide greater detail of the distribution but the number of quantiles used here was deemed appropriate to obtain an adequate correction of the distribution and the provision of greater detail at the distribution tail. The means for each resulting quantile bin were calculated and used to calculate monthly quantile correction factors for each PPE member. These factors are the ratio of observed means to those of each ensemble member for each monthly quantile bin. An examination of the correction factors (Figure 3) demonstrates that not only do the RCM variants overestimate mean daily wind speed (correction factors < 1) they also do not reproduce the distribution of daily wind speed values and consequently smaller corrections are required for the higher quantiles. This indicates that applying a monthly correction factor to the whole distribution would have resulted in an underestimate of extreme daily wind speeds. It is notable though that for most ensemble members the correction factor is more uniform throughout the distribution during summer months indicating that there may be different sources of bias throughout the year and possible problems associated with winds accompanying winter storms.

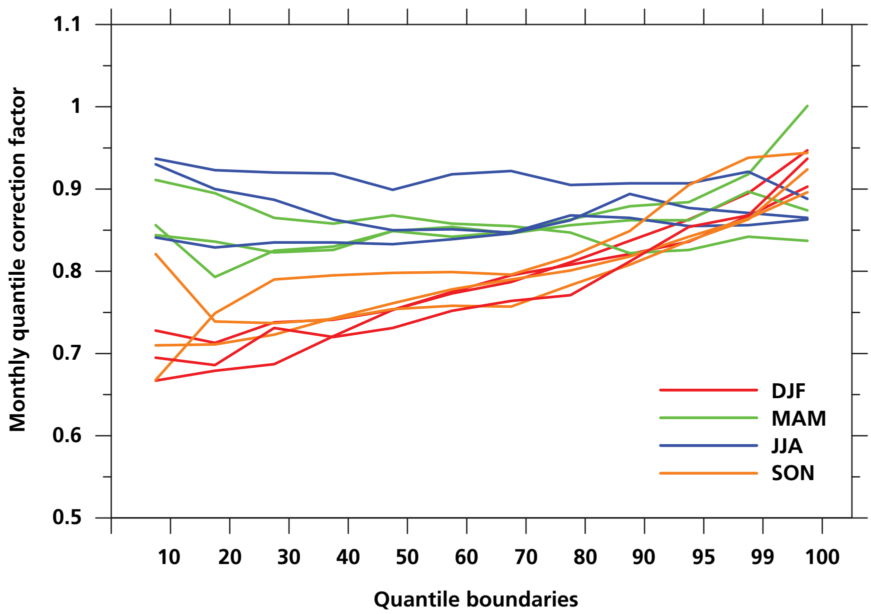
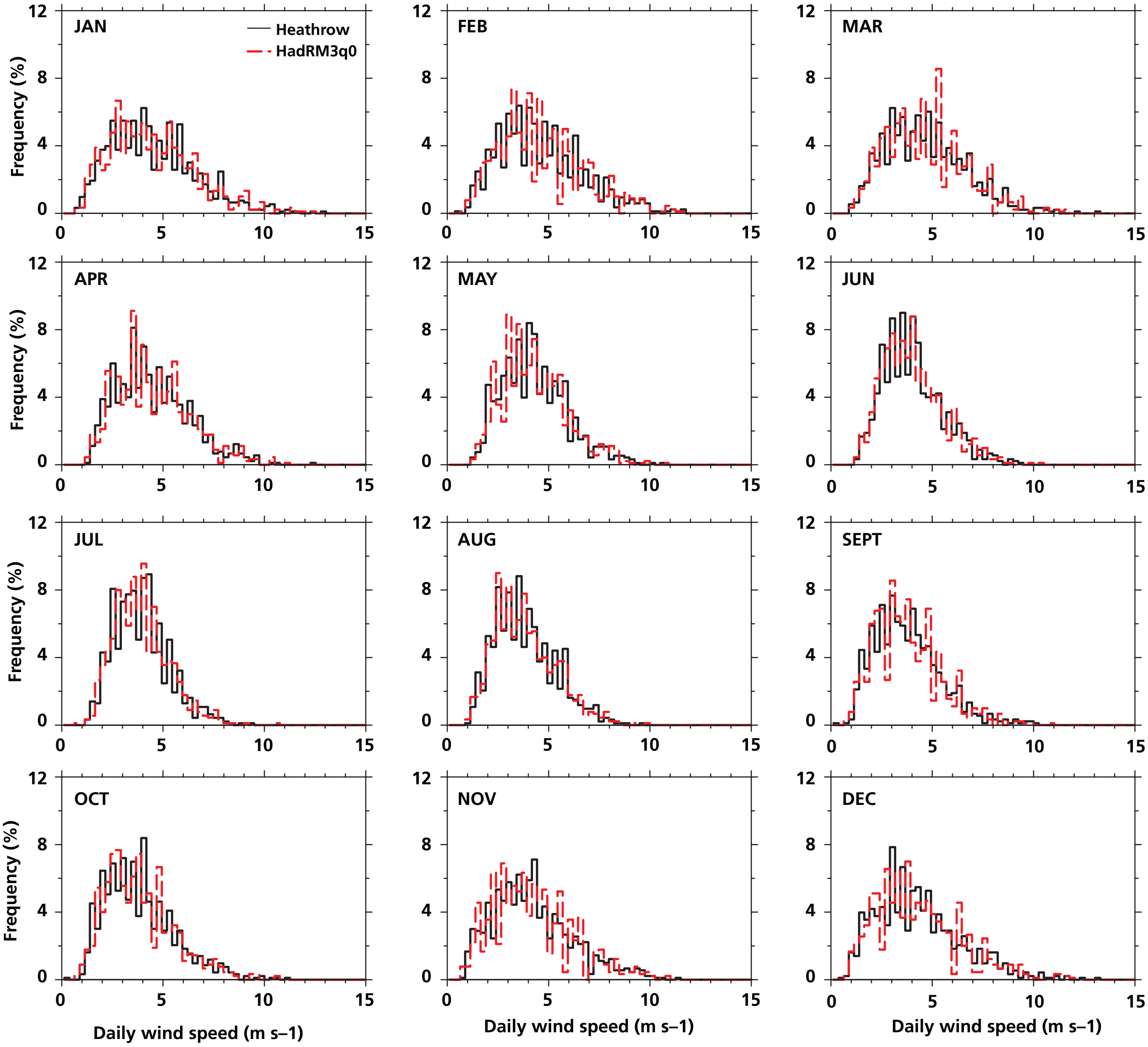


Figure 3: Quantile correction factors for ensemble member q0 (afgcx). Correction factors are shown for each month, categorised by season. The wind speed percentiles define quantiles comprising daily mean wind speeds in the range 0–10th percentile, 10–20th percentile… ..99th–100th percentile.

These correction factors were used to scale the simulated daily wind speed values for each quantile bin for the PPE 1961–1990 data and for 2 future 30-year periods of interest to the CREW project centred on the 2020s and 2050s (assuming the same biases to be present in the model simulations throughout the future simulations the same quantile correction factors may be applied to the corresponding quantiles for the future daily mean wind speeds for each ensemble member). As a result of this procedure the quantile corrected RCM monthly mean wind speeds for each ensemble member reproduce the distributions of the Heathrow observed series over the period 1961–1990 (Figure 4).

Further work needs to be undertaken with regard to the more extreme tail of the distribution for events that are of interest to, for example, engineers in the built environment. Several avenues are suggested for future development of appropriate methodologies for using wind data from the PPE. Firstly, development of methods with a physical basis for correcting RCM biases and downscaling PPE output for the use in local climate change impact assessments. Alternatively, discussions with colleagues suggest that the Weibull distribution may be useful in developing a downscaling/correction methodology which may be more appropriate for extreme values in the tail of the distribution. Such an approach has been described by Pryor *et al*. (2005) who downscaled Weibull parameters of wind speed probability distributions for an ensemble of GCMs using multiple linear regression. Further development of this method may prove useful.

Figure 4: As for Figure 2 but after quantile correction of ensemble member HadRM3q0.



References

Brown S., Boorman P., McDonald R, Murphy J, 2009. Use and interpretation of surface wind projections from the 11-member Met Office Regional Climate Model ensemble. UKCP09 Technical Note.

Pryor, S. C., Schoof, J. T., Barthelmie, R. J., 2005. Climate change impacts on wind speeds and wind energy density in northern Europe: empirical downscaling of multiple AOGCMs, *Climate Research*, **29**, 183–198.

Acknowledgements

This work was undertaken as part of the CREW project which was funded by the Engineering and Physical Sciences Research Council (EPSRC) project no. EP/F037422/1. This work was supported by a NERC post-doctoral Fellowship award to Dr Hayley Fowler (2006–2010) NE/D009588/1. Output from the 11-member perturbed physics ensemble may be downloaded from the Climate Impacts LINK project website at http://badc.nerc.ac.uk/data/hadrm3-ppe-uk/.